Engineering Case Library

ECL 223

THE 3.5 MILLIMETRE SLIDING LOAD

This case tells about some work done by Larry Renihan and Jerry Mathews at Hewlett-Packard in Palo Alto. Larry designed the sliding load, a small precision device used for calibrating connectors. Jerry prepared the production plans.

THE 3.5 MILLIMETRE SLIDING LOAD

Because of its large research and development department, the Hewlett-Packard Corporation continually adds new products to its inventories. Sometimes the development of a product leads to the need and subsequent development of another product. Such is the case for an instrument that Hewlett-Packard is currently readying for production, for example, the 3.5 millimetre sliding load. This instrument is designed to terminate Hewlett-Packard's 3.5 millimetre co-axial connector.

An electrical connector is a device that joins two or more electric wires in a manner similar to that of an electric plug. The system differs from a normal electrical system in that the current flows over the wires instead of through them. For this reason, the diameter of the connector is important since there will be a certain amount of power loss due to the difference between the connector diameter and the wire thickness.

With the assistance of a computerized Network Analyzer, the 3.5 mm sliding load determines the impedance of the connector. The sliding load is essentially a measuring device that is used to calibrate the computer. The connector and sliding load are coupled and then connected to the computerized Network Analyzer (See Figure 1). The arm of the sliding load is moved up and down until no signal flows through the connector. The signal loss can then be read directly from a printout from the computer. This comes about because the sliding load absorbs all of the signal that gets through the connector. In this way, the signal loss is known and it is possible for the computer to take into account this impedance when in a system with the connector.

The connector-computer system is used in the communications industry. Corporations like Motorola use the system in the manufacture of radios and other products. In many instances, the system would be used by the manufacturers to calibrate their equipment. In another example, the United States Government uses similar instruments to check their electronic equipment. The sliding load is also needed in many satellite communication systems.

The Design Process

Mr. Larry Renihan designed both the 3.5 mm sliding load and the 3.5 mm connector for Hewlett-Packard. Mr. Renihan's background uniquely qualifies him to design a complex mechanical/electronics instrument. He received a B.S. in

electrical engineering and spent several years working in a mechanical engineering machine shop. He had been working for Hewlett-Packard's research and design division for some thirty years. He was asked to design the 3.5 mm sliding load while working on the 3.5 mm connector.

Devices for other frequencies similar to the one designed by Mr. Renihan are presently on the market. There is a twofold reason for Hewlett-Packard's wanting to design their own instrument: First, they can make it to their specifications so that it will fit the already-existing connector. They will not have to place a special order with another company that produces a sliding load. Secondly, Hewlett-Packard feels that they can make a better sliding load and sell it at a lower price. Buyers looking through a Hewlett-Packard catalogue will be more likely to buy a complete unit rather then components from two companies. Not only will the sliding load itself make money for Hewlett-Packard, but it should also increase the sales of the connector.

The design of the 3.5 mm sliding load serves as a kind of cornerstone at Hewlett-Packard because it is their first metric instrument. The device is designed, produced and sold with all of the dimensions in metric units. The firm feels that the conversion to the metric system is inevitable and that the sooner they begin to manufacture metric products, the easier the complete conversion will be. (Hewlett-Packard does have plants in other countries where metric units are used, but until now only English units were used in their United States factories.) To facilitate the reading of the drawings by others involved in the production of the sliding load, the drawings contain a conversion table which converts the prescribed millimeter dimensions into inches and gives the equivalent tolerances (See Figure 2).

Mr. Renihan designed and produced two models of the 3.5 mm sliding load for his own research use, to see if such a device would work with the 3.5 mm connector. After he satisfactorily tested the model, Hewlett-Packard asked him to design the instrument for production. Working by himself, the entire design process took Mr. Renihan about six months. Although they were unable to release a list of all the parts or the drawings of the parts, Hewlett-Packard did provide some information on the relative size of the instrument. It is made up of about 14 parts, the largest of which is 255 mm long with a diameter of 9.4 mm. A drawing which shows approximately what the product will look like can be seen in Figure 3. Because of the close fit of the sliding parts, the tolerances must be small. Typical tolerances for non-critical (length) dimensions are ± 0.5 mm, while the tolerances for

important diameter dimensions are $\pm$ 0.003 mm.

The Manufacturing Process

After their completion, the design drawings were given to Mr. Jerry Matthews, a registered professional manufacturing engineer. Mr. Matthews has been at Hewlett-Packard for five years, having spent several years working for other firms. He is currently enrolled at Stanford University where he will receive an M.S. in Industrial Engineering next year.

Mr. Matthews must take the design drawings and decide what manufacturing processes are necessary to produce the parts for the instrument. In manufacturing, the primary consideration is the cost of the production with the specifications given as constraints: Is the cost justified by the specifications? The part should be produced as economically as possible within the prescribed tolerances. Sometimes, the tolerances can be changed to cut the production cost. In the case of the 3.5 mm sliding load, this generally is not possible because the small tolerances are essential.

The 3.5 mm sliding load presents several problems because of its small size, its function and the accuracy with which the parts must be made. Each of the 14 parts must be machined separately and most require a special tooling which Hewlett-Packard does not have. Thus, since it takes 2 or 3 months to get the special tools, Mr. Matthews' first responsibility is to identify and order the necessary tools. Another problem has been the selection of materials to use for the instrument. For some of the parts, the prime requirement is that the metal have good electrical conduction properties. Other parts have to be durable, not because they will have to support any kind of load, but because the instrument has to be long-lasting. All of the parts have to be machinable because of the importance of accurate dimensions. Three metals were chosen:

1) Beryllium-copper was chosen because of its conductivity and resilience;
2) Stainless steel was picked because of its strength and resistance to corrosion;
3) Aluminum (7075-T6) was selected for the main tube-like body of the instrument since this part will be anodized black.

The energy-absorbing electronic loads are made of a poly-iron substance which completely absorbs the electrical energy. In some cases, an epoxy will be used to cement various parts together.

The machining aspect of production is proving to be a little more difficult than the material selection was. Again, it is the accuracy to which the parts must be produced that is creating the problem. The raw material is first ground to size for some parts. Then, parts are machined using several different processes. The main body is gun drilled, which drills deep holes very accurately, and then reamed to size. Some parts are drilled by standard methods while others are held by a collet. A milling machine cuts the slots in the body of the sliding load. One hole must be so precise that it should be broached. The first broach manufacturer contacted by Mr. Matthews refused to produce the broach because the hole is too small and they do not feel that they can make a satisfactory tool. If he is unable to order a broach from another manufacturer, Mr. Matthews may have to try to produce the hole by electro-forming. This is not desirable because copper would be used in electro-forming and Mr. Matthews would rather not use copper. In addition, electro-forming is a very expensive process. Finally, all parts go through finishing processes.

Mr. Matthews relies mostly on experience and technical knowledge to determine what processes to use. He has been working with most processes and materials long enough to know which methods work best on certain materials. If one aspect of the process does not work as well as he had expected, he will justify a change in the process, a new machine, or change the material. In many instances, a team of engineers who did not work on developing a particular project will review the manufacturing procedure after a year or so to insure that an instrument is being effectively produced, and will suggest changes if necessitated by changing production requirements and volume.

Presently the biggest problem that Mr. Matthews has anticipated is the maintenance of suitable tolerances, for example, those specified by the dimensions of the slots in the body of the instrument. The difficulty may arise during the milling of these slots. When the tube is milled, internal stresses may be released which would cause the slot to open or close to such a degree that the tolerances could be violated. To solve the problem, Mr. Matthews will use a combination of theoretical analysis and experimentation to find the mill cutter size that will give the correct slot width when this is taken into account.

Once he has decided on the tools that will be used, Mr. Matthews lists the parts and the tools that are needed to make each part. He also lists the cost and delivery time of each tool. In this way, he gets some kind of idea of the

number of processes that will be necessary and the total cost of manufacturing the entire instrument. A sample chart of the tools for 6 of the parts appears in Figures 4 and 5. He then completes a similar chart that details the machining that must be done, the tools to be used and an estimate of the total number of man-hours necessary to perform each process. This gives Hewlett-Packard some idea of how long it will take to produce each instrument and the total manufacturing cost. The manufacturing order is sent to the machine shop where the production of the parts takes place.

The kind of production output that Mr. Matthews is aiming for is less than 10 instruments a month. The main reason for this limited output is that the instrument is so specialized. Also, there is not yet a large market for the 3.5 mm sliding load, so there is no need to create a large inventory of the devices. Mr. Matthews feels the demand could increase because of increased radio traffic and the development of new frequencies. Should this greater demand develop, Hewlett-Packard can increase production to meet the demand. Depending on the final cost of production, Mr. Matthews predicts that Hewlett-Packard will be able to sell the products for between $400 and $600 each. This price is less than the price of a similar type instrument made by another company and is high enough to insure a profit on each sale.

Mr. Matthews expects production to be ready in about 6 months. The Hewlett-Packard 3.5 mm sliding load should appear on the market in late 1976 or early in 1977.

This study would not have been possible without the patience and assistance of Jerry Matthews of Hewlett-Packard who spent several hours of his own time answering my many questions. He was also kind enough to provide me with the documents that appear as exhibits in the paper, and others that I did not use but that helped me a great deal.

I would also like to thank Larry Renihan who also answered some of my rather simplistic questions.

After reviewing the paper, Jerry Matthews asked for the inclusion of a statement from the Hewlett-Packard Company which acknowledges that although some technical inaccuracies are present in this paper, the Hewlett-Packard Company feels that the educational value of the study is fulfilled.

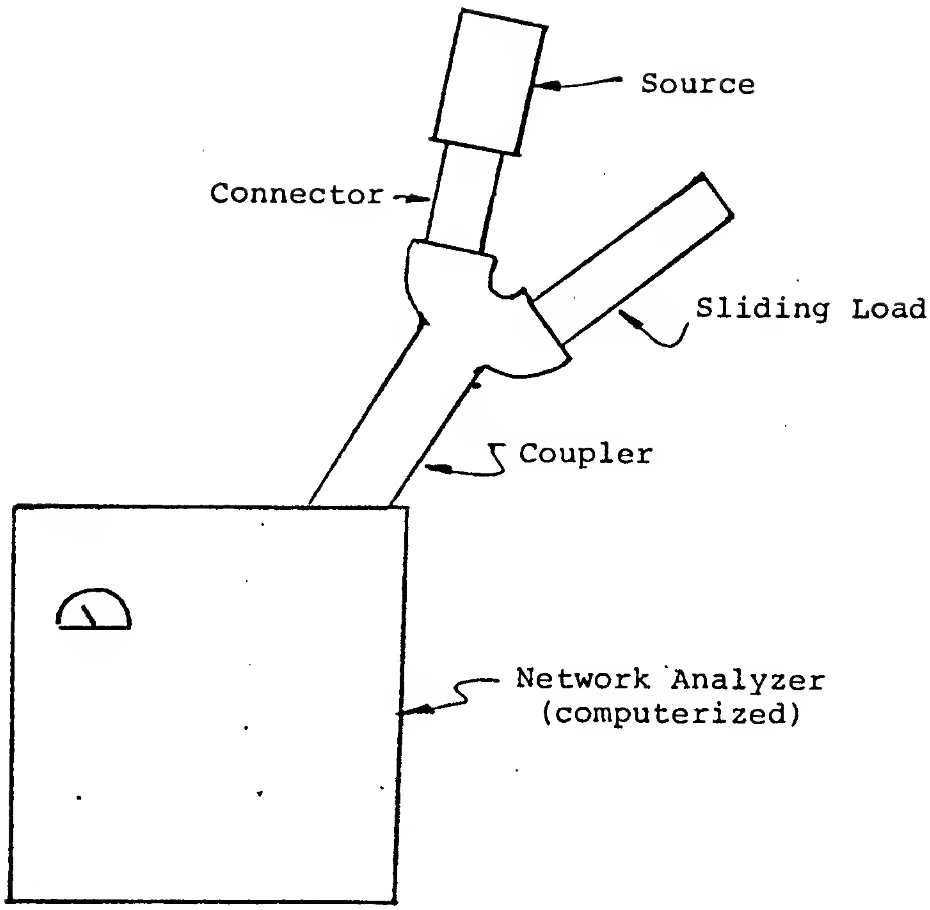


Figure 1

Schematic Representation of the
Computerized Network Analyzer Connector System

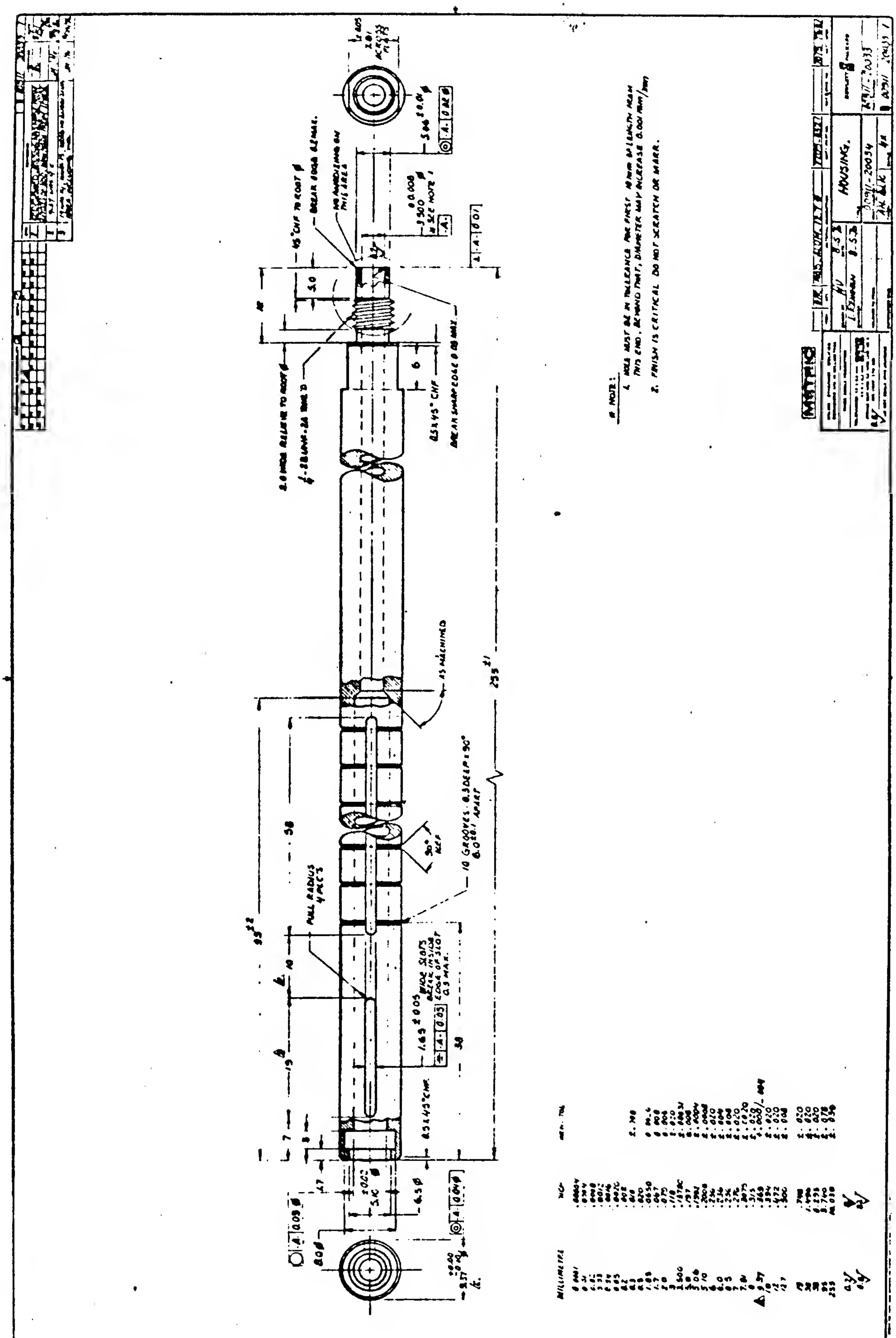


Figure 2

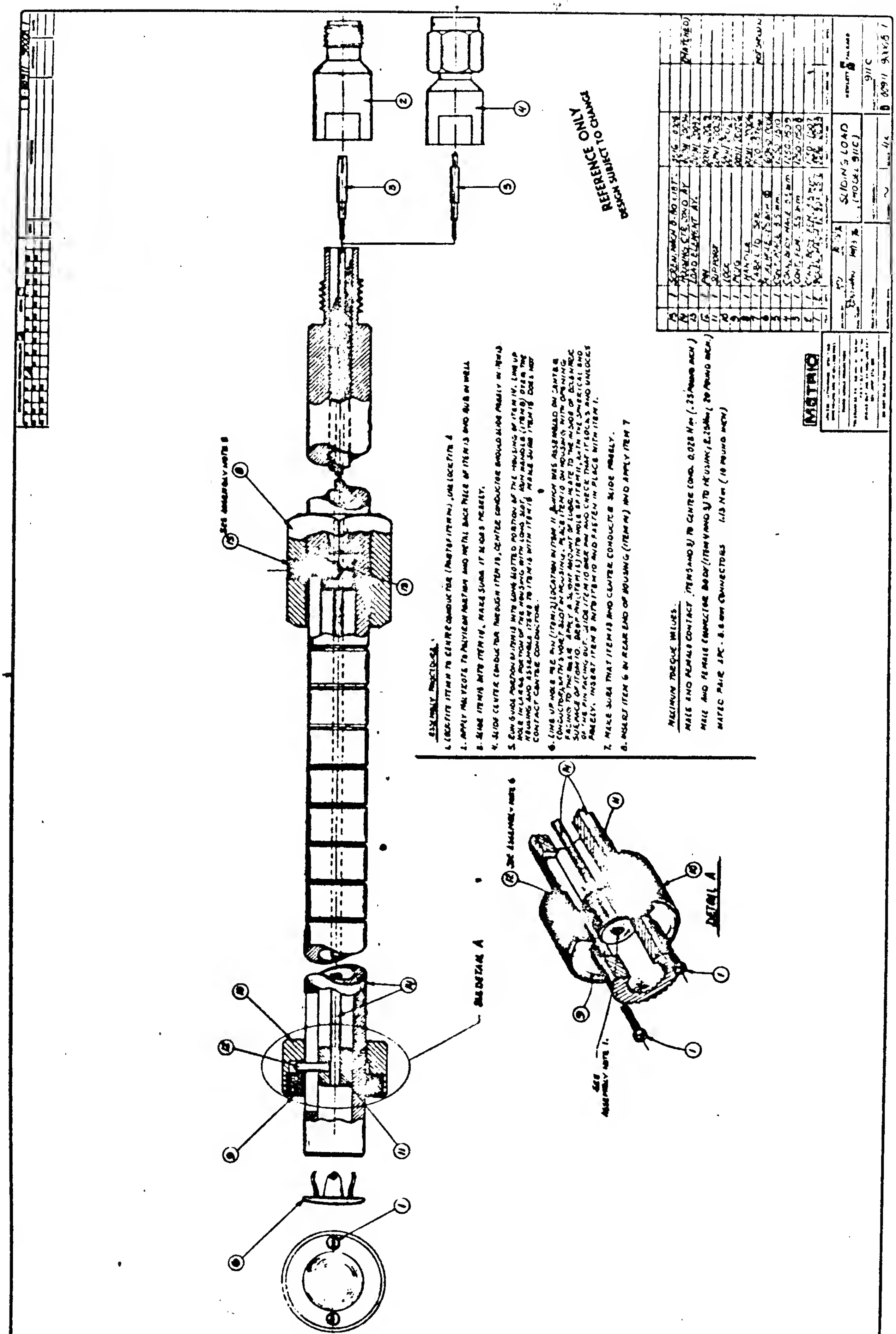

REFERENCE ONLY
DESIGN SUBJECT TO CHANGE
METRIC
DETAIL A
SLIDING LOAD (MODEL 911C)

Figure 3

NEW INSTRUMENT TOOLING & MFG. PLAN

T NAME SLIDING LOAD

Y MODEL NO. 911C

MAY JUNE JULY AUG. SEPT OCT NOV

PART NO	PART NAME	TOOL NAME	TOOL NO.	EST HRS DES	EST HRS BLD	TOTAL EST DOLLARS
033	HOUSING					
	✓	PLATE PLUG	158867	2	4	150
	✓	VISE JAWS	58649	AUXIL		
	✓	TEMPLATE	158858			
	✓	GUNDRILL	1583[illegible]	PURCH		100
	✓	BUSH	158361			25
	DELETED	GUNDRILL	1588[illegible]			55
		BUSH	1588[illegible]			25
		GUNREAM	158834			55
		BUSH	158835			25
		GUNDRILL	58827			55
		BUSH	1588[illegible]			25
		GUN [illegible]	58830			55
	✓	BUSH	158831			25
	✓	GUNDRILL	158824			125
	✓	I.D. GAGE	1588[illegible]			175
	✓	I.D. GAGE	1588[illegible]	PURCH		360
	✓	MANDREL	158841	2	4	150
	✓	MANDREL	1588[illegible]	2	4	150
	✓	FORM TL	1588[illegible]	2	5	175
	✓	FORM TL	1588[illegible]	2	4	150
	DELETED	FORM TL	[illegible]842	2	4	150
	✓	FIXTURE	121[illegible]	—		[illegible]
	✓	[illegible]K TL	158845	2	3	125
		SUB TOTAL		55	70	4333
		TOTAL				

HEWLETT hp PACKARD

* For symbol designation see new Inst Summary

LAB PROJECT NO 2158

LOCATION CODE C4-7270

EST. MATURE SALES/MONTH

DATE 10/6/76

PREPARED BY JP Matt[illegible]

SHEET ___ OF ___

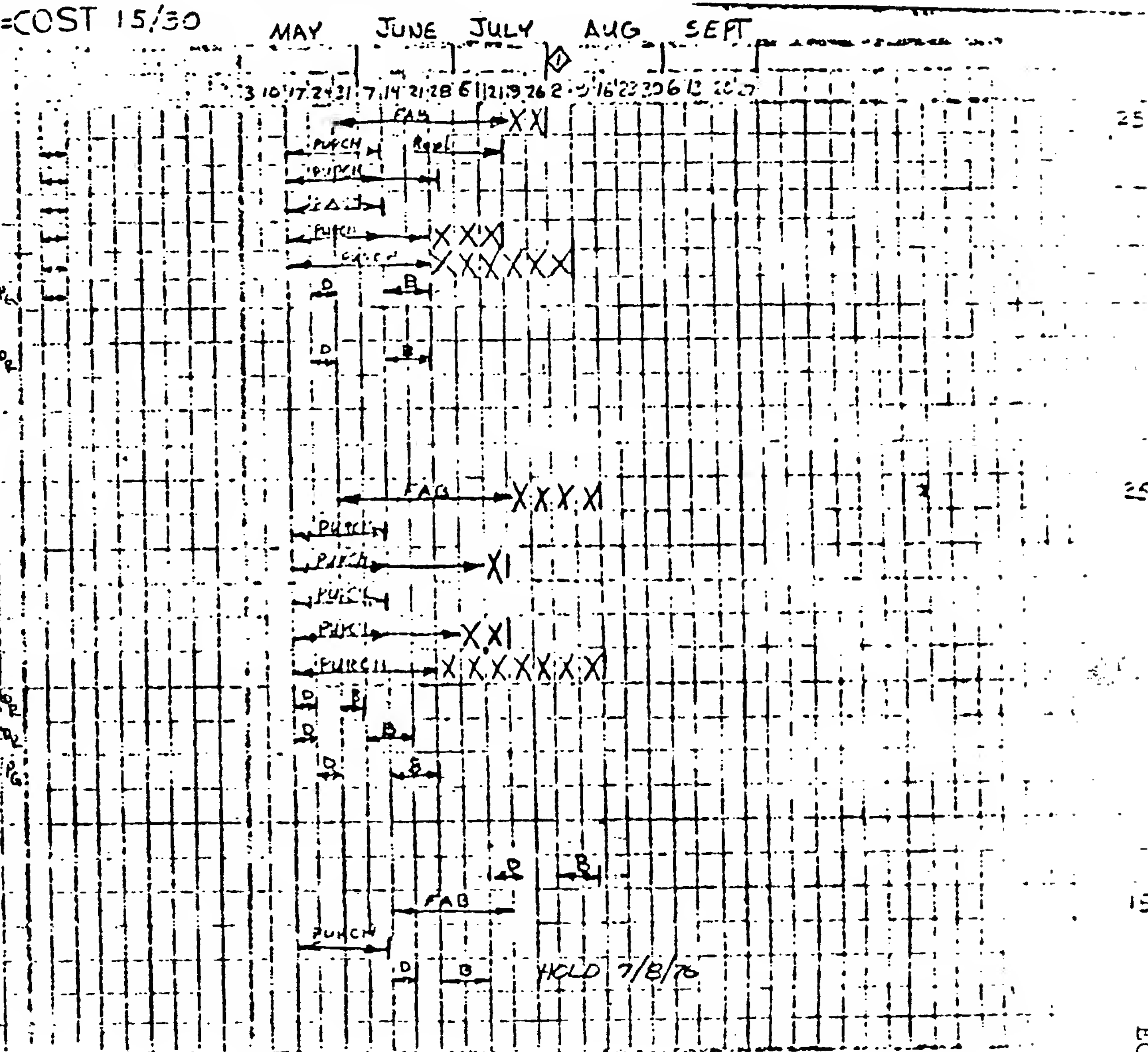
SLIDING LOAD

9110

NEW INSTRUMENT TOOLING & MFG. PLAN

1= SET UP/RUN 2=COST 15/30

		TOOL No	DES	BLD	
BODY					
11.5 / .293	GUN DRILL	158832	PURCH		55
7.243 / 4.672	DRILL BUSH	158833	PURCH		25
	GUN REAMER	158834	PURCH		55
	REAM BUSH	158835	PURCH		25
89mm x 3.5mm	I.D. GAGE	15583?	PURCH		360
	MANDREL	158841	2	4	150
	FORM TOOL	158842	2	4	150
	FIXTURE	121636	—		EXISTS
2 GUIDE					
	GUN DRILL	158827	PURCH		55
13.0 / .452	DRILL BUSH	158828	PURCH		25
	GUN REAM	158830	PURCH		50
8.971 / 6.061	REAM BUSH	158831	PURCH		25
	ID GAGE	158829	PURCH		175
	FORM TOOL	158838	2	5	175
	FORM TOOL	158839	2	4	150
	MANDREL	158843	2	4	150
	GUNDRILL FIXT	121626	—		EXISTS
	MILL TEMP.	158858	2	4	150
CENTER COND.					
	ITAL GAGE	158837	PURCH		105
4.75 / .285	HI. FIXTURE	15884?	2	5	175
6.377 / 5.347	COLLET ADAPT.	1588?5	4		
	SUB TOTAL		13		43.2485



2158

04-7210

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DATE 5/27/76

PREPARED J.R. MATHEWS

Figure 5